Spatial Inequalities in Premature Mortality in Great Britain

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Abstract:

Premature mortality exhibits strong spatial patterns in Great Britain. Local authorities that are located further North and West, that are more distant from its political centre London and that are more urban tend to have a higher propensity to die prematurely. Premature mortality also tends to cluster among geographically contiguous and proximate local authorities. We develop a novel analytical research design that relies on spatial pattern recognition to demonstrate that an empirical model that contains only socio-economic variables can eliminate these spatial patterns almost entirely and never less than 80 percent. As our findings suggest, policy-makers cannot hope that health policies alone suffice to significantly reduce inequalities in health. Rather, it requires strong efforts to reduce the inequalities in socio-economic factors, or living conditions for short, in order to overcome the spatial disparities in health, of which premature mortality is a clear indication.

1. Introduction

The majority of premature deaths in Great Britain can be prevented. Preventable premature mortality results from adverse living conditions, unhealthy lifestyle choices or because individuals do not seek or do not receive medical treatment often or early enough. The National Institute for Health and Care Excellence estimates that in England alone around two thirds of deaths of those aged 75 or below (around 103,000 fatalities) are largely avoidable. The reason is that the most important direct causes, such as cancer, heart disease, stroke, respiratory and liver diseases "are preceded by long periods of ill-health mostly caused by lifestyle related factors" (National Institute for Health and Care Excellence 2015: 2).

The probability that an individual dies prematurely is not equally distributed across Great Britain, however. Quite the contrary: Great Britain faces a larger spatial inequality in premature mortality than most other Western European countries (Doorslaer and Koolman 2004). These inequalities in premature mortality across Great Britain show three strong spatial patterns. Higher than average premature mortality rates appear clustered in i) early industrial centres of textiles, coal and steel, ii) Scotland, and iii) urban areas. All three factors together contribute to excess premature mortality in Glasgow. In fact, this early industrial city in Scotland is infamous for the fact that, as yet, nobody has managed to satisfactorily identify the causes for what has been dubbed the 'Glasgow effect': the extremely high premature mortality and associated low life expectancy of Glaswegians compared to other part of Great Britain.

This article uses a novel research design to analyse spatial inequalities in premature mortality. We employ different techniques of pattern recognition across space – spatial clustering in terms of geo-coordinate location, centrality, contiguity, proximity and urbanity – to identify the degree to which each of these spatial patterns exist. We then regress the propensity for premature mortality at the local authority level on a battery of socio-economic factors – factors that explain premature mortality very well. We then analyse how well our socioeconomic model explains the spatial patterns we have identified. Thus, our research is dominantly interested in the degree to which socio-economic factors explain the recognized spatial patterns in premature mortality. Put differently, we evaluate the 'power' of our model by the degree to which socio-economic factors account for and eliminate the identified spatial patterns in premature mortality.

This novel research design allows us to demonstrate that spatial patterns in the socio-economic determinants of health almost completely explain spatial patterns in premature mortality. We show that the local authority characteristics of average income, dependency on welfare benefits, educational qualification, sectoral employment composition, socio-economic position, and ethnic composition explain the vast majority of cross-sectional variation in premature mortality at the local authority level. The spatial inequalities or divides in premature mortality are therefore highly associated

with and, we would argue, caused by spatial inequalities or divides in living conditions that these socio-economic factors represent.

Our paper, first of all, contributes to the scientific and public debate on regional health inequalities in Great Britain. Of course, the existence of spatial inequalities in premature mortality is known not just to health researchers (Langford and Bentham 1996; Law and Morris 1998; Doran et al. 2004; Woods et al. 2005; Thomas et al. 2010; Hacking et al. 2011; Acheson 1998), but also to the UK's government (Wells and Gordon 2008). Recently, the Westminster government placed health inequalities across Great Britain high on its political agenda. The UK's Health Secretary Jeremy Hunt called the scale and scope of regional differences in premature mortality shocking and concluded that "this (…) variation in early and unnecessary deaths means people's lives are needlessly cut short, and that cannot continue unchecked." For once, the opposition agrees. Representatives of the Labour Party called for a "one nation approach" to end health inequalities.[1] We contribute to this public and scientific debate by arguing that health policies and health policy reforms are not sufficient to eliminate regional disparities in premature mortality and seek to cure symptoms – regional variation in diseases and ill health that result in premature mortality – where it would be superior to tackle the root causes of regional variation in premature mortality – socio-economic inequality and its consequences on lifestyle choices that impact health.

Second, our research also contributes more generally to the literature on health inequalities. We focus more clearly than previous studies (e.g., Langford and Bentham 1996) on the extent to which socio-economic characteristics of Great Britain's local authorities explain the strong spatial inequalities in premature mortality. Whether or not an individual dies prematurely ultimately depends on whether he or she acquires a life-threatening disease. However, whether or not a local authority has a higher or lower aggregate premature mortality rate depends on the socio-economic characteristics of the local authority.

Third, our paper also contributes to the general analysis of spatial patterns beyond those in premature mortality. Recently, the spatial econometric revolution (Anselin 2010, 2013; Neumayer and Plümper 2016) has drawn the attention to neighbourhood (contiguity) and proximity effects. For example, analyses of income convergence in the US (Rey and Montouri 1999) or the European Union (Ramajo et al. 2008) and the strategic interaction among governments have been based on spatial models relying on contiguity or inverse distance as connectivity variables for operationalizing spatial dependence (Plümper and Neumayer 2010). We show here that important spatial patterns exist well beyond the traditional clustering of outcomes along the lines of contiguity or proximity of units of analysis. We find that premature mortality also clusters by increasing degrees of being geo-located in the North and in the West of Great

[1] All quotes are cited from BBC news at http://www.bbc.com/news/health-22844227).

Britain, by increasing degrees of being removed from the political centre of Great Britain (London) and by decreasing degrees of urbanity.[2]

2. The Geography of Premature Mortality: A Spatial Pattern Recognition Approach

Spatial analyses of social, economic, and political outcomes often treat spatial dependence as nuisance rather than as the subject of interest for analysis. In this view, geographical patterns are interpreted as a violation of Gauss-Markov conditions and researchers have no substantive interest in the underlying causes for spatial patterns. From an empirical perspective, it then suffices if researchers estimate a model with spatially lagged residuals to correct for errors which are potentially correlated across space – a spatial error model. More recently, however, social scientists widened their perspective and started to analyse spatial dynamics (Bennett 1991; Goodchild et al. 2000) and network effects (Keele and Titiunik 2016; Boehmke et al. 2016) with a genuine theoretical interest on spatial influences in social interactions. While much of this research was facilitated by methodological advances, the existence of spatial clusters and patterns is increasingly regarded no longer as an empirical nuisance but rather becomes a phenomenon of theoretical interest (Franzese and Hays 2008, Neumayer and Plümper 2016).

In this section, we develop an approach that allows researchers to quantify spatial patterns in geo-coordinate location, centrality, contiguity, proximity and urbanity. Before we do so, we first map spatial patterns to demonstrate the severity of health inequalities across Great Britain. Our spatial pattern recognition analysis confirms the suggestive findings of these maps: Great Britain is highly uneven in premature mortality, and these inequalities strongly cluster spatially in numerous ways.

Mapping Spatial Patterns

In a world in which all individuals were identical and had identical living conditions, premature mortality would not systematically vary across space. Though random processes would cause some variation in premature mortality of individuals and in premature mortality rates at local authority levels, these variations would not cluster along spatial dimensions. Needless to say, individuals and living conditions are not identical. In reality, health outcomes including premature mortality show very strong spatial patterns. This holds especially for Great Britain. By simply mapping premature mortality rates, these become visible. Figure 1 illustrates the geography of premature mortality of, respectively, men and women across local authorities in England, Wales and Scotland.

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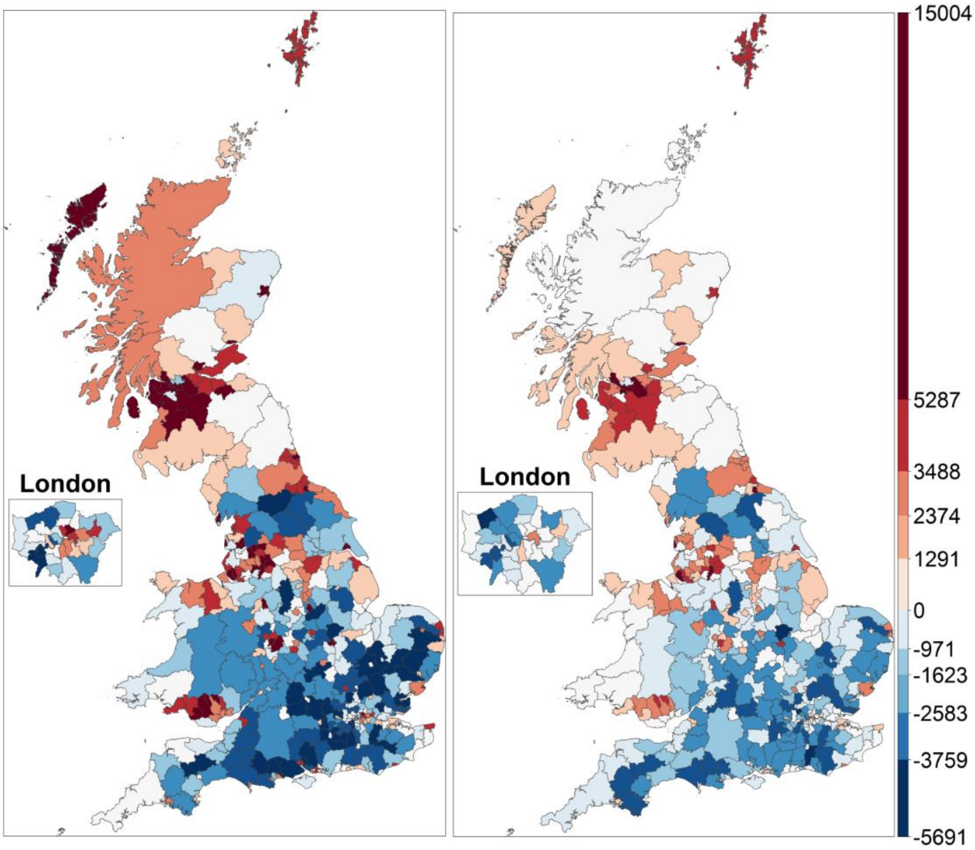
[2] A further geographical dimension not explored in our study is altitude. For example, presidential elections in Austria in 2016 showed a pattern that went beyond the urban-rural divide. Rural areas were more likely to vote for the right-wing candidate Hofer the greater their altitude above sea-level.

We define premature mortality as the probability of dying before the age of 70. We compute a standardized propensity of premature death in local authorities based on the life tables for England, Wales and Scotland for the period 2012-2014.[3] The maps show increasing degrees of above median (increasingly darker red) and below median (increasingly darker blue) premature mortality. It becomes immediately evident that the probability of premature death shows strong regional patterns. Even at a first glance, it is evident that the odds that an individual dies prematurely are much higher in the North-West and rapidly decline as one moves towards the South-East of Great Britain. Accordingly, the lowest premature mortality rates occur in a belt that stretches from East Anglia to Dorset, while the highest premature mortality rates can be observed in and around Glasgow. Upon closer inspection, additional micro-patterns become visible. Larger industrial cities such as Birmingham and Liverpool have higher premature mortality rates than surrounding, more rural, neighbourhoods. Even Aberdeen and Dundee stand out from the surrounding areas, and so do Bristol, Hull and Grimsby.

Figure 1: Above and Below Median Premature Mortality of Men (left) and Women (right) in Great Britain



[3] Data was provided by the Office of National Statistics for England and Wales and the National Records of Scotland.

In comparison to Scotland, where areas with above median premature mortality rates are common, England and Wales only have higher than median premature mortality rates in the old industrial areas around Manchester, Birmingham, East London, and North and South Wales. East London also looks interesting because above median premature mortality rates for men contrast with premature mortality rates for women that lie close to or even below the median.

Statistical Spatial Pattern Recognition

Spatial patterns can not only be visualized through maps, they can also be quantified using various appropriate model specifications. We use five simple analyses to describe different average spatial patterns: first, we use the geo-coordinate location of local authorities, specifically the degree to which they are located further North and further West on the British Isles, as explanatory variables in a regression model, using data from the UK Data Service Census Support. This research strategy captures the well-known North-South and West-East divides in premature mortality in Great Britain (Thomas et al. 2010). Second, we run a regression that estimates whether premature mortality increases as we move away from the City of London. We use the near-by City of London rather than the London borough of Westminster as the centre since, together with the Isle of Scilly, the City of London is one of only two local authorities that we excluded from the regression analysis because their low population sizes render premature mortality figures unreliable.[4] Third, we estimate the degree to which premature mortality clusters among contiguous local authorities. For this analysis, we regress premature mortality on a contiguity-weighted row-standardized spatial lag variable. Fourth, we use inverse distance rather than contiguity as the connectivity variable, thus employing an inverse distance-weighted row-standardized spatial lag variable. Finally, we estimate whether premature mortality increases with increasing urbanity, defined as the population density of a local authority, with data taken from the British 2011 census.

Geo-coordinate location: North-South and West-East Divides

Table 1 presents results from models where we regress, respectively, male and female premature mortality on continuous measures of 'Northness' and 'Westness' of local authorities on the British Isles. The divides are stronger for men than for women and the North-South divide is stronger than the West-East divide. Table 1 also demonstrates that the North-South divide, which is strong in England, virtually does not exist within Scotland. In contrast, the West-East divide exists in England, Scotland (though not for women), and Great Britain, but its effects are largest in Great Britain. In other words, spatial divides along the geo-coordinate location of local authorities become much weaker if we analyse the nations that form Great Britain separately. For Great Britain as a whole, the North-South and West-East divides jointly account for 26 percent of the

[4] All our findings remain robust to using Westminster as the centre of Great Britain.

variation in premature mortality of men and 30 percent of the premature mortality of women, as the R-squared values show.

Table 1: North-South and West-East Divides in Premature Mortality

	Great Britain		England		Scotland	
	Male	female	male	female	male	female
Northern location	0.0078	0.0057	0.0102	0.0079	-0.0007	-0.0033
	(0.0010)	(0.0007)	(0.0013)	(0.0009)	(0.0038)	(0.0033)
Western location	0.0068	0.0042	0.0036	0.0020	0.0142	0.0014
	(0.0016)	(0.0011)	(0.0018)	(0.0012)	(0.0077)	(0.0054)
Observations	378	378	324	324	32	32
R-squared	0.259	0.302	0.187	0.251	0.062	0.038

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Centrality: Distance to London

Centrality is an important theoretical concept in all social sciences. For example, network analyses perceive the unit as central when it has the largest number or the strongest links to other units (Marsden 2002; Dorff and Ward 2013). We use a political-economic definition of centrality here and define centrality as proximity to the City of London such that centrality declines as the distance to London increases. As results reported in table 2 demonstrate, centrality almost perfectly substitutes geo-coordinate location in our analysis. Both geographical variables explain the same variance – a result caused by the artefact that London is located in the South-East of Great Britain. For other countries this second measure of detecting spatial patterns will produce very different results from geo-coordinate location analyses. Perhaps more importantly, the centrality effect does not exist in Scotland.

Table 2: The Centrality Effect in Great Britain, England and Scotland

	Great Britain		England		Scotland	
	male	female	male	female	Male	female
Distance from London	0.0105	0.0073	0.0119	0.0086	-0.0017	-0.0034
	(0.0011)	(0.0008)	(0.0016)	(0.0010)	(0.0041)	(0.0033)
Observations	378	378	324	324	32	32
R-squared	0.242	0.272	0.158	0.194	0.003	0.027

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Contiguity: Clustering Among Neighbouring Districts

Table 3 shows results from regressing premature mortality on contiguity-weighted row-standardized spatial lag variables. This variable measures, for each unit of observation, the average premature mortality rate in contiguous local authorities. Accordingly, we test to what extent premature mortality in one district correlates with the average premature mortality of neighbouring districts (Neumayer and Plümper 2016).[5] As the explained variance (R-squared) statistics reported in table 3 show, contiguity accounts for a larger share of the variation in premature mortality in Great Britain than the North-South and West-East variables of geo-coordinate location or the centrality measure do. In other words, high premature mortality tends to cluster quite strongly among geographically contiguous local authorities in Great Britain and so does low premature mortality. However, strikingly, in Scotland spatial clustering among neighbouring districts seems largely absent.

Table 3: Clustering among Contiguous Districts in Great Britain, England and Scotland

	Great Britain		England		Scotland	
	Male	female	male	female	male	female
Spatial lag (contiguity)	0.7224	0.7650	0.6920	0.7158	-0.0736	0.1332
	(0.0755)	(0.0681)	(0.0740)	(0.0720)	(0.3516)	(0.3812)
Observations	373	373	323	323	29	29
R-squared	0.277	0.346	0.218	0.264	0.002	0.006

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Proximity (Inverse Distance): Clustering Among Close-by Districts

Table 4 shows results from regressing premature mortality on a proximity- instead of contiguity-weighted row-standardized spatial lag variables. This variable measures, for each unit of observation, the average premature mortality rate in local authorities where other local authorities are weighted by the inverse of their Euclidian distance to each other. Accordingly, we test to what extent premature mortality in one district correlates with the average pre-mature mortality of proximate districts. We find that proximity clustering explains a much smaller share of the variation than clustering among contiguous districts.

[5] We lose six observations due to Island local authorities not being contiguous to any other authorities.

Table 4: Clustering among Proximate Districts in Great Britain, England and Scotland

	Great Britain		England		Scotland	
	male	female	Male	female	male	female
Spatial lag (proximity)	1.9100	1.9156	1.5749	1.4032	1.6734	2.8745
	(0.420	(0.4157)	(0.4198)	(0.4082)	(1.9262)	(1.7114)
Observations	378	378	324	324	32	32
R-squared	0.061	0.070	0.049	0.043	0.040	0.165

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Urbanity: The Urban-Rural Divide

In table 5 we report results from regressing premature mortality on the population density of local authorities in order to test for an urban-rural divide. We find evidence for higher premature mortality rates in cities for both men and women in Great Britain, England, and Scotland. However, the adverse effect of urbanization is stronger for men than for women and much stronger for Scotland than for England. We suggest, however, that readers should take the coefficients for Scotland with some scepticism. The number of local authorities in Scotland is low. Nonetheless, future research needs to address the Scottish urban-rural divide in premature mortality based on micro-data.

Table 5: The Urban-Rural Divide in Great Britain, England and Scotland

	Great Britain		England		Scotland	
	male	female	Male	female	male	female
Population density	22.3832	5.3561	28.1430	9.4712	299.6819	169.2805
	(9.5638)	(5.1169)	(10.7731)	(5.8908)	(49.1718)	(36.2001)
Observations	378	378	324	324	32	32
R-squared	0.035	0.005	0.075	0.020	0.361	0.309

Robust standard errors in parentheses. Constant included, but coefficient not reported.

3. The Socio-economic Determinants of Premature Mortality

The observation that “everything is related to everything else, but near things are more related than distant things” (Tobler 1970: 236) suggests spatial dependence between units in the sense that premature mortality in one district is caused by premature deaths in near districts. However, as social scientists have known since at least Galton (1889), social phenomena may be spatially clustered even though no causal spatial dependence exists. Spatial correlation in outcomes can also be caused by a similarity of units since “everything resembles everything else, but near things are more similar than distant things” (Neumayer and Plümper 2016: 181; Quah 1993). With spatial similarity, premature mortality is spatially clustered because the causes of premature mortality are spatially clustered – and not because premature mortality in one district causally

increases the propensity for premature mortality in neighbouring districts.[6] We can think of three factors that are spatially correlated with spatial patterns in premature mortality: genetic variation across people living in Great Britain, climatic conditions, and socio-economic factors. We discuss them in turn, starting with what we regard as implausible alternatives to socio-economic determinants.

Genetic and Climatic Variation as Alternative Explanations to Socio-economic Determinants

Genetic variation across Great Britain was caused by early immigration, the effects of which are still visible in today's population. In fact, the British Isles were populated by four different gen pools: early immigration was dominated by Saxons in the South-East, the Britons in the South-West, the Picts in the North-East and the Irish in the North-West. These main migration paths still appear as genetic variation across local gen pools. However, the effect of this genetic variation on the propensity for various diseases remains weak and causal mechanisms rather complex (Duff 2006). Much empirical evidence is also confounded by a potential minority effect (Winkleby et al. 1998): Some of the ethnic groups have minority status and this status, and any preferential treatment of ethnic minorities that comes with it, may affect the propensity for diseases more than potential genetic differences. Thus, in the absence of genetic discrimination, it remains unlikely that genetic dispositions explain the large variation in premature mortality in the UK, even though the current genetic distribution still resembles to some extent the migration routes into the British Isles.

Likewise, climatic conditions influence mortality. More people die during the winter months than in summer. These winter excess deaths are not predominantly caused by annual flu epidemics. Rather, diseases of the respiratory and circulatory system appear to be aggravated by low temperatures and damp weather. Does this imply that people living in areas that have more adverse climatic conditions – lower average temperatures, higher annual rainfall, fewer hours of sunshine – on average have a higher probability to die prematurely? Clearly, the North and the West receive much more precipitation and enjoy fewer hours of sunshine than the South-East of Great Britain. The North is also colder than the South. However, research (Anderson and Bell 2009) demonstrates that differences in climatic conditions have little influence on mortality – only unusual extreme weather exerts a strong influence on mortality. Even though unexpected adverse climatic conditions may increase mortality rates, regions with expected poor climatic conditions do not necessarily experience per se higher mortality rates. Individuals adjust to the climatic conditions of the region they live in. Therefore, the effect of weather on mortality is highest under unusual extreme weather conditions. Research on US cities demonstrates that a heatwave increases mortality in the North, where heat is uncommon, but not in the South, where heat is common. Likewise, cold periods had a larger effect on mortality in the South where low temperatures are

6 Epidemic diseases demonstrate the possibility of spatially dependent premature deaths, however.

uncommon, than the North, where low temperatures occur every winter (Anderson and Bell 2009).

Socio-economic Determinants of Premature Mortality

Spatial patterns in premature deaths suggest the existence of strong inequalities in health more generally across Great Britain. In trying to explain these inequalities, researchers have pointed towards wealth and economic development as main explanatory factors (van Doorslaer et al. 1997; Deaton and Paxson 2001: Marmot 2002). While wealth and technological progress reduces premature mortality, poverty and the existence of 'old' and 'dirty' industries are associated with a higher propensity for premature mortality. International comparisons of premature mortality suggest that once countries have passed a per capita income of 40,000 Dollar, premature mortality does not decline further (Deaton and Paxson 2001: 116). Below this threshold, the chance of dying prematurely increases – moderately for women, rapidly for men (Deaton and Paxson 2001: 117).

It may appear a somewhat philosophical question whether income causes good health or whether poverty causes illness. While the argument in political debates typically runs from poverty to illness, a historical account would suggest that rising wealth leads to health. For premature mortality the question appears to be just the same: for political debates, poverty causes premature deaths, whereas historically we observe a declining propensity for premature death in areas that have become wealthier.

For current governments, it is more important that the steeper the income-health gradient, the more premature deaths can be prevented. In Great Britain, mortality from liver diseases, respiratory diseases, cardiovascular diseases and cancer are on average two times more likely among the poorest quintile of the population than among the richest quintile of the population (Department of Health 2013), suggesting that a large share can, in principle, be prevented. But poverty is not the only potential culprit. Other factors that influence premature death, most of which correlate with poverty, include professional occupation (blue collar versus white collar) and social status (Marmot and Allen 2014; Marmot et al. 1984, 1991, Marmot 1994, 2002), and education (Elo and Preston 1996; Muennig 2010). Many health economists doubt that income has an independent health effect. Instead, they argue that the estimated effect of income on premature mortality results from lack of precise control for confounding factors such as nutrition, alcohol consumption, drug abuse, weight, and so on (Ruhm 2000; Deaton and Lubotsky 2003). This argument rests entirely on a narrow definition of the word cause. If we were to accept this definition, then smoking would not kill, only lung cancer kills.

Using a broader definition of causality, we are interested in the root causes of premature mortality. Of course, most individuals that perish prematurely die because they acquired a deadly disease, but in a broader perspective, we want to know why some individuals got this deadly disease while others did not. In a narrow view, income has no causal

effect on health: if we make 1,000 poor individuals significantly richer, but force them not to change their behaviour and not to spend the additional income, the additional income will presumably have little or no influence on health. In a broad perspective on causality, however, if we increase the income of individuals without imposing such constraints on them, then individuals that become richer will change their behaviour: they move house, start purchasing healthier food, give up their job, potentially reduce alcohol consumption, buy additional education, spend more on health care, and so on. In other words, income influences lifestyle choices, and lifestyles affect health in the long run. Regardless of whether income directly influences health or not, income and education arguably are the two most powerful instruments to change behaviour and a change in behaviour will affect health. In our terminology: income is a root cause, but not the causal mechanism for health, with the relation between these two factors also far from being perfectly understood: the estimated effect of income on health declines by roughly 25 percent after controlling for risk factors or for employment status (Deaton and Lubotsky 2003: 120).

Both the root causes for premature mortality and the causal mechanisms directly influencing premature mortality rates vary across local authorities. The distribution of income shows spatial patterns: mean and median income are higher in the South-East. Poverty in turn clusters in the North of England, in Wales and in the Scottish Highlands. The share of individuals with no or low educational qualifications is highest in Wales and in the Northern parts of England. Occupations that provide high socio-economic status follow similar spatial patterns. Given that all these factors are not mutually independent from each other and that it remains disputed what can be regarded as root causes and what as causal mechanisms, we do not evaluate the power of our empirical estimation model according to whether variables have a statistically significant effect on premature mortality. All we are interested in here is the combined explanatory power that socio-economic factors jointly exert on premature mortality.[7]

We use four categories of socio-economic variables. Our first set of variables utilizes the explanatory power of average income and poverty. We measure poverty by proxy as the population share of benefit claimants. Poverty can exist in poor and rich neighbourhoods. Our second battery of variables accounts for the distribution of educational attainment. Like income, education does not directly prevent premature mortality. However, it indirectly influences premature mortality through its influence on professional choice, income, nutrition, smoking habits and so on. Better educated people are healthier on average not because they are better educated, but because on average better educated people lead healthier lives. Our third set of control variables account for the distribution of employment across economic sectors and the socio-economic status that comes with specific professions. Sectoral composition can directly influence

[7] Disentangling the mutual conditional and indirect effects is also an important task, but not one that we are trying to deliver in this paper. Instead, our analysis exclusively explores to what extent the spatial patterns in the battery of socio-economic factors eliminate the spatial patterns in observed premature mortality.

premature deaths through industry-specific risks and accidents. Sector-specific employment may also indirectly affect health. For example, working in shifts, which is much more common in some sectors than in others, has been associated with a significantly higher propensity for coronary heart diseases (Kawachi et al. 1995; Knutsson 1988). Sectoral composition and socio-economic professional status also influence lifestyle choices. Finally, we control for the ethnic composition of local authorities. Since we control for professional socio-economic status and income, these variables mostly account for the influence of culture on behaviour relevant to premature mortality in the form of ethnic heterogeneity in nutritional intake, alcohol consumption, smoking and other risk factors influencing premature mortality.

4. Research Design

As mentioned in section 2, we define premature mortality as the probability of dying before the age of 70, calculated on the basis of life tables for England, Wales and Scotland for the period 2012-14. This gives a standardized propensity of premature mortality: the number of individuals that do not reach the age of 70 in an artificial cohort of 100,000. Our findings are robust to employing instead the lower age threshold of 60 or the higher age threshold of 75 as the definition of premature mortality (detailed results not shown). We analyse premature mortality separately for men and women.

Our socio-economic explanatory variables come from the British 2011 census and from other statistics provided by the Office of National Statistics (ONS) and the Scotland Census. Specifically, we use information on the highest level of educational qualification (broken down into 5 categories), socio-economic status composition (8 categories), the types of economic sectors that provide employment (18 categories), social welfare benefits claimants, and ethnic composition (5 categories). For comparability, these characteristics are measured as a proportion of the relevant local authority population (e.g. the percentage of the local population that has achieved a certificate of higher education and above). In addition, we include average income in a local authority. The data provided by the ONS and the Scotland Census was complete for all 380 local authorities in Great Britain, with the exception of five missing observations for mean income. To address this issue we replaced the missing data with the mean of 100 imputed values. The imputations were carried out using a linear model that included the same socio-economic variables used in the analysis of premature mortality (except mean income) plus population density.

Analyses were conducted using linear ordinary least squares regressions on premature mortality in 378 of the 380 local authorities in Great Britain. Following Wells and Gordon (2008), we exclude data for the City of London and the Isle of Scilly because their low population sizes render premature mortality figures unreliable. Allowing for non-linear effects by including second degree polynomial terms of our explanatory variables results in only a small increase in goodness-of-fit with the data and leaves our

substantive findings unchanged (results not reported here). Estimation using the Poisson model gives substantively identical results (again, results not shown).

5. Explaining the Spatial Patterns in Premature Mortality

Results presented in table 6 show that the socio-economic characteristics of local authorities explain between 87 percent (men) and 83 percent (women) of the cross-sectional variation in premature mortality in Great Britain.[8] This substantial explanatory power highlights the importance of socio-economic inequality across local authorities as drivers of inequality in premature mortality. As we have discussed in the previous section, due to the non-independence of the explanatory variables, individual effects should not be interpreted in isolation. Many variables have direct, as well as indirect effects, while our model only estimates direct effects.[9] Yet, for our research interest only the joint explanatory power of the battery of socio-economic variables is relevant.

Table 6: The Socio-Economic Determinants of Premature Mortality

	male	female
Mean income	-0.0002	0.0001
	(0.0002)	(0.0001)
Benefit claimants	0.0055	0.0050
	(0.0015)	(0.0012)
Highest educational qualification composition		
GCSE (grades D-G)	0.1989	0.1319
	(0.0494)	(0.0384)
GCSE (grades A-C)	-0.0097	-0.0016
	(0.1001)	(0.0840)
A level	-0.0996	-0.1119
	(0.1052)	(0.0793)
Certificate of higher education and above	0.1700	0.0697
	(0.0712)	(0.0573)
Employment by economic sector composition		
Agriculture	-0.2236	0.0524
	(0.1562)	(0.0971)
Mining	0.0086	-0.0181
	(0.1709)	(0.1107)
Manufacturing	0.1063	0.1131
	(0.0969)	(0.0601)
Gas & Electricity	0.0031	0.0392
	(0.2157)	(0.1601)
Water	0.3241	0.1579
	(0.3630)	(0.2693)
Construction	-0.2709	-0.1544

[8] For expositional reasons only, we express the dependent variable as an actual percentage (rather than as the number of survivors out of a hypothetical population of 100,000). Naturally, this does not change any of the substance of the estimations.

[9] For the same reason, we do not indicate levels of statistical significance.

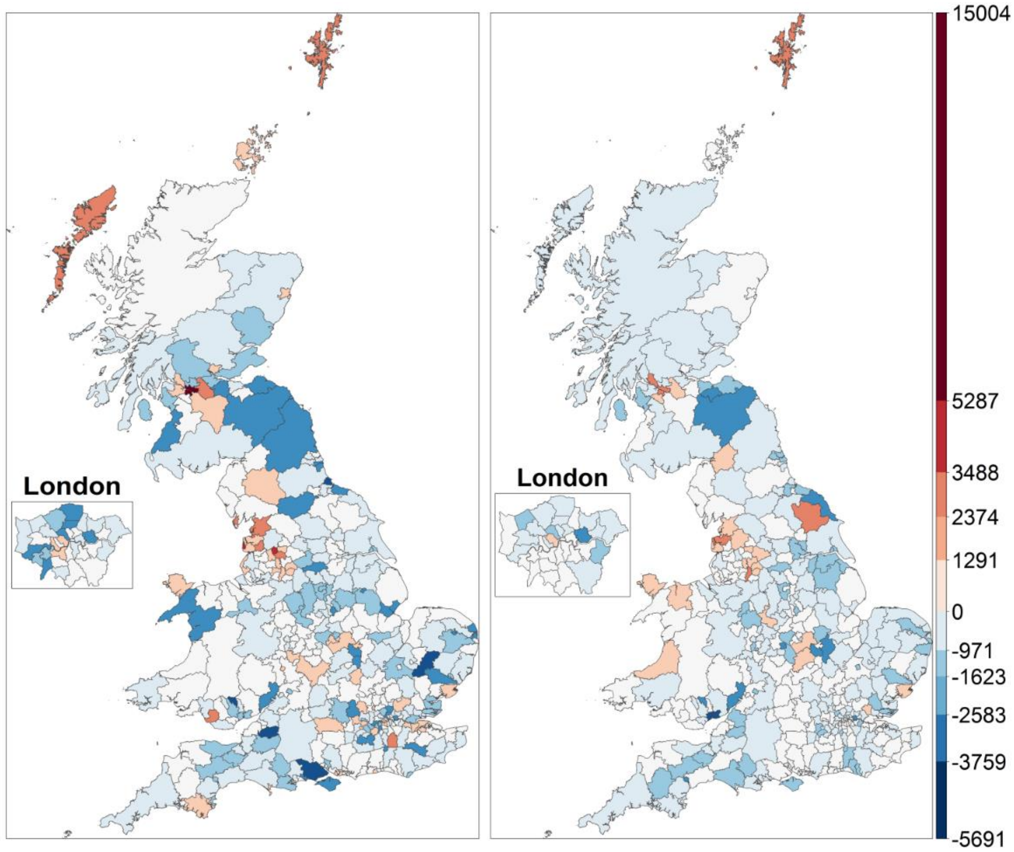
	(0.1395)	(0.0848)
Retail	-0.0763	0.0000
	(0.1021)	(0.0698)
Transport	0.1155	0.0772
	(0.1066)	(0.0604)
Hospitality	0.2414	0.1079
	(0.1389)	(0.0948)
Information Technology	0.3237	0.1728
	(0.1193)	(0.0697)
Finance	0.1470	0.0328
	(0.0986)	(0.0575)
Real estate	0.1277	0.2720
	(0.3794)	(0.2480)
Academic/Science	0.3862	0.2212
	(0.1368)	(0.0902)
Administration	0.3721	0.1436
	(0.1683)	(0.1243)
Public Administration	0.0627	0.0641
	(0.1003)	(0.0611)
Education	-0.0811	-0.0815
	(0.1085)	(0.0713)
Health	0.3903	0.1869
	(0.1067)	(0.0663)
Socio-economic status composition		
Higher managerial	-0.9617	-0.5427
	(0.1445)	(0.1000)
Lower managerial	-0.2620	-0.2952
	(0.1134)	(0.0911)
Intermediate occupations	-0.1730	-0.0798
	(0.1102)	(0.0872)
Small employers	-0.1776	-0.2217
	(0.1284)	(0.0879)
Lower supervisory	-0.1713	0.0197
	(0.2104)	(0.1575)
Semi-routine occupations	-0.4342	-0.3803
	(0.1196)	(0.1018)
Routine occupations	0.1398	-0.0880
	(0.1114)	(0.0803)
Ethnic composition		
Mixed	0.3218	0.4318
	(0.2536)	(0.1854)
Asian	0.3291	0.3661
	(0.1763)	(0.1204)
Black	0.2323	0.3207
	(0.1806)	(0.1262)
White	0.3686	0.4027
	(0.1758)	(0.1211)
Constant	-0.0926	-0.1598
	(0.1736)	(0.1132)
Observations	378	378
R-squared	0.871	0.831

Robust standard errors in parentheses. Omitted reference categories are ‘not working’, ‘other ethnicity’, ‘entry level educational qualification’ and ‘other sector’, respectively.

For a cross-sectional estimation, the socio-economic factors explain a stunningly high share of the variation in premature mortality for both men and women. But do these characteristics fully explain the spatial patterns in observed premature mortality like the North-South and West-East divides and the clustering among contiguous local authorities? Figure 2 visualizes, separately for men (map on the left) and women (map on the right), the degree to which the spatial patterns that were so prominent in figure 1 have declined through the explanatory power of the socio-economic factors in our model. These maps visualize the residuals from our estimation model, that is, the variation in premature mortality unexplained by the socio-economic explanatory variables. Even a superficial comparison of figures 1 and 2 reveals that the spatial patterns in premature mortality of men and women are strongly reduced by the socio-economic factors included in our model.

Yet, some minor spatial patterns survive. Pockets or spatial clusters of unexplained excess premature mortality for men and women continue to exist in and around Glasgow and Manchester, whereas lower than expected premature mortality is rather unsystematically distributed.

Figure 2: Unexplained Variation in Premature Mortality for Men (left) and Women (right)



Maps provide powerful visualizations but they do not give us the answer to our core research question, namely to what extent the battery of socio-economic factors have eliminated the spatial patterns in premature mortality. To address this question, table 7 compares the North-South and West-East divides before (observed values) and after (residuals) we fitted our model. After controlling for socio-economic factors, the North-South and West-East divide decline by between 80.6 and 93.6 percent. This provides strong evidence that the vast majority of these geographical divides in Great Britain are caused by geographic divides in socio-economic factors. Yet, table 7 also demonstrates that the divides are not entirely eliminated. The coefficients of the geographical location remain positive, even if much reduced in size.

Table 7: North-South and West-East Divides in Observed Values and Residuals

	Observed male	Observed Female	Residuals male	Residuals female	Decline male	Decline female
North-South Divide	0.0078	0.0057	0.0005	0.0005	93.6%	91.2%
	(0.0010)	(0.0007)	(0.0005)	(0.0004)		
West-East Divide	0.0068	0.0042	0.0013	0.0007	80.6%	83.3%
	(0.0016)	(0.0011)	(0.0007)	(0.0005)		
Observations	378	378	378	378		
R-squared	0.259	0.302	0.024	0.022		

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Given that London is located in the South-East of Great Britain, centrality strongly correlates with geo-coordinate location, therefore we do not repeat the analysis for centrality here. The declines in spatial patterns are almost identical to the ones reported for the North-South and West-East divides. Instead, tables 8 and 9 indicate the degree to which the spatial clustering in premature mortality among geographically contiguous or geographically proximate local authorities is eliminated by our estimation model. The former declines by between 88.3 and 94.4 percent, while the latter is completely eliminated for men and almost completely eliminated for women.

Table 8: Spatial Clustering Among Contiguous Districts in Observed Values and Residuals

	Observed male	Observed Female	Residuals male	Residuals female	Decline male	Decline female
Spatial lag (contiguity)	0.7224	0.7650	0.0404	0.0894	94.4%	88.3%
	(0.0755)	(0.0681)	(0.0306)	(0.0315)		
Observations	373	373	373	373		
R-squared	0.277	0.346	0.007	0.029		

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Table 9: Spatial Clustering Among Proximate Districts in Observed Values and Residuals

	Observed male	Observed Female	Residuals male	Residuals female	Decline male	Decline female
Spatial lag (proximity)	1.9100 (0.4204)	1.9156 (0.4157)	-0.0562 (0.1510)	0.0749 (0.1623)	102.9%	96.1%
Observations	378	378	378	378		
R-squared	0.061	0.070	0.000	0.001		

Robust standard errors in parentheses. Constant included, but coefficient not reported.

Finally, table 10 estimates the extent to which our estimation model explains the urban-rural divide. Between 80.6 and 88.3 percent of the urban-rural divide is eliminated by the socio-economic determinants in our estimation model. For women, this represents the comparatively smallest reduction in spatial pattern, which suggests that for women differences in premature mortality may result from socio-economic factors not covered by our model or by a generally unhealthier life in cities potentially caused by pollution and stress.

Table 10: Urban-Rural Divide in Observed Values and Residuals

	Observed male	Observed female	Residuals male	Residuals female	Decline male	Decline female
Population density	22.3832 (9.5638)	5.3561 (5.1169)	2.6274 (2.4780)	1.0377 (1.7396)	88.3%	80.6%
Observations	378	378	378	378		
R-squared	0.035	0.005	0.004	0.001		

Robust standard errors in parentheses. Constant included, but coefficient not reported.

6. Conclusion

Spatial patterns in premature mortality across local authorities in Great Britain are rooted in the same spatial patterns in socio-economic factors or, for lack of a better word, in living conditions. Accounting for the geographical differences in living conditions largely explains the geography of premature death across local authorities in Great Britain. We also found some, but rather minor, gender differences. The inequalities that result in spatial patterns are stronger for men than for women. Yet, the socio-economic factors eliminate these patterns to an almost identical extent for both men and women. This implies that adverse socio-economic conditions influence the health of men slightly more than the health of women – or to put it differently: lifestyle and other choices of men seem to depend more on socio-economic factors than the choices of women.

While socio-economic factors strongly reduce the spatial patterns they do not fully eliminate them. For example and perhaps most importantly, Glasgow's high premature mortality rate and low life expectancy remain puzzling. It tops the list of unexplained excess premature mortality for both men and women in Great Britain. Glaswegian men are about 14.5 and Glaswegian women about 8.7 percentage points more likely to die prematurely than, respectively, men and women in the average local authority. Our model reduces the excess probability of premature mortality that is not caused by socio-economic factors for Glaswegian men to 5.6 percent and for women to 3.3 percent. These figures may be considered a substantial reduction, but almost 40 percent of the premature mortality in Glasgow remains unexplained by our model. Like all other scholarly attempts to fully account for the poor health status and excessively high premature mortality rates of Glaswegians, our model fails to deliver a convincing answer to the puzzle raised by the 'Glasgow effect' (Reid 2011).

Our analyses also offer some findings relevant to the Department of Health's plan to reduce or even eliminate health inequalities. The Department of Health seems to believe that by providing "local areas with information to help them understand their own position" and by targeting "specific health challenges" the regional disparities in premature death can be eliminated.[10] Our research suggests that this political programme is likely to be over-optimistic. The clear socio-economic background of health inequalities across Great Britain identified by our study suggests that health policies alone will not eliminate the regional health inequalities. Accordingly, we believe that a consistent combination of economic, social and education policies are needed to more fully overcome health inequalities. Perceiving health inequalities as the consequence of socio-economic inequalities offers a further advantage since it does not make sense to use health policies to cure diseases which would not develop if socio-economic conditions were less detrimental for certain parts of society. Unnecessary premature mortality should be prevented by eliminating the root causes of this mortality, and not by developing strategies that reduce mortality once individuals are unnecessarily affected by diseases.

That UK governments have failed to fulfil their self-proclaimed targets of reducing, over the period 2001 to 2010, by 10 per cent the gap in life expectancy between the bottom quintile of local authorities and the population as a whole is telling and supports our interpretation (Marmot 2010: 45; Mackenbach 2011). Our analysis suggests that only improvements in living conditions in localities with excess premature mortality are likely to significantly reduce health inequalities. Admittedly, to change living conditions is a much more challenging political task than the reallocation of health funding to some disadvantaged regions. Tackling the geographical divides in living conditions represents a huge task to policy makers, but without it the chances to reach the political goal of more equal health conditions across local authorities are slim.

[10] As quoted in BBC news at http://www.bbc.co.uk/news/health-22844227.

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